Status of Emission Inventories

And

Modeling Update

Introduction

This section will address items 4 and 5 in the EPA Checklist for June 2003 Progress Report. See attached checklist for reference.

Since October 2000, Tennessee has been part of the Arkansas-Tennessee-Mississippi Ozone Study (ATMOS). This study and the organization that supports it were designed to address attainment of the 8-hour National Ambient Air Quality Standard (NAAQS) for ozone in portions of this geographical region. The issues in item 5 of the checklist were addressed in great detail in the draft technical protocol for the study provided by the modeling consultant Systems Applications International (SAI) / ICF. The relevant sections of that protocol document are attached and referenced below.

Obviously, ozone Early Action Compacts (EAC) were not a consideration in the original design of the study. The extremely tight timeline of the EAC process has forced some issues to be quickly addressed including:

- Additional geographical areas within the grids had to be defined to match the EAC structure.
- An additional ambient monitor added since the beginning of the study had to be accounted for.
- Updates to the monitor design values based on more recent ambient measurements were determined.
- Relevant updates to the modeling emission inventory were provided to the consultant.
- Selection and evaluation of at least one additional meteorological scenario was begun.
- Additional Urban Airshed Model (UAM) runs to account for these changes were begun.

While there is much to be accomplished in a very short timeframe, the existing ATMOS study provides Tennessee the basis for meeting the deadlines.

Checklist Items

4. The UAM modeling consultant, Systems Applications International (SAI) / ICF requested relevant emission inventory updates – mobile and stationary – from state and local agencies be provided by mid June. Updates were provided. See attached email from Wayne Davis, University of Tennessee Knoxville to Jay Haney, ICF for details and some issues concerning the 91 counties under state jurisdiction.

5.a. See attached Section 1 of the draft technical protocol.

5.b. See attached Section 3 of the draft technical protocol.

5.c. See attached Section 3 of the draft technical protocol.

5.d. See Introduction above. Preliminary results from model revisions are expected shortly.

5.e. Funding has been allocated to carry out the actions listed in the Introduction above. Also see attached Section 6 of the draft technical protocol.

If more detailed information on any of these issues is needed, the entire draft technical protocol document can be provided. An evaluation of results from updated model runs and scenarios can be provided in the next progress report. It is also suggested that the ATMOS website be visited at the following URL for additional background details:

http://atmos.saintl.com/

Review Checklist for June 2003 Progress Report

1. Was the list of control measures submitted in the June 16, 2003 milestone report (and the EAC plan) developed with local stakeholder input?

   Yes ☐ No ☐

2. Is the local stakeholder process for the Early Action Compact (EAC) area documented?

   Yes ☐ No ☐

3. Description of the local stakeholder process:

   Documentation should include the following information, but is not limited to items on this list:

   a. The primary local organization responsible for EAC activities.
   b. The lead contact.
   c. Organizational chart for subgroups or list of stakeholders working on various activities.
   d. What meetings were held, and what level of public participation was there?
   e. Which stakeholders were invited and level of participation?
   f. When/where were meetings held?
   g. How were the meetings advertised? How were invitations issued?
   h. What is the website for the local EAC program (if there is one)?
   i. Description of Outreach efforts.

4. What is the status of development of emissions inventories? What issues have been identified in the development of the inventories?

5. Photochemical Modeling for Attainment Demonstration.

   a. General information: Has a model been selected?
   b. What is the base year for the ozone episode selected?
   c. What is the status of the meteorological model development?
   d. What is the status of the modeling activities?
   e. What issues are being encountered, i.e., funding, model meeting performance criteria, etc.?

6. Discuss, to the extent possible, the geographic area for which control measures are expected to be implemented.

7. Discuss, to the extent possible, any early anticipated resource constraints.

Ron Redus - Re: ATMOS EAC new episode/emissions request

From: "Dr. Wayne T. Davis" <wtdavis@utk.edu>
To: "Haney, Jay" <JHaney@icfconsulting.com>
Date: 6/3/2003 9:53 AM
Subject: Re: ATMOS EAC new episode/emissions request
CC: <pdorai@utk.edu>, "Ron Redus" <ron.redus@state.tn.us>, Jeongran Yun <jyun@utk.edu>

Jay,

Regarding the request for updated info, we will be sending you several things that you requested.

First, the attached file represents our latest point source files for the State of Tennessee for the 91 counties that we are responsible for with respect to emission inventories for 1999. This file is a better, more accurate file than the Version 2.0 NEI file which you were going to use. We do the submittals to EPA and the Version 2.0 is somewhat deficient in that some sources were not included. The attached file should be used for all TN counties except Shelby, Knox, Hamilton, and Davidson. Those four county inventories are conducted by the four local agencies. Obviously, the attached file would be used except for the EGUs where CEMS data should be sustituted. Source additions and deletions should be minimal between 99 and 01. So I would suggest that you grow the emissions according to your technique used previously.

We recommend using the Version 2 NEI for area and nonroad mobile. We did look at the VErsion 2 to be sure that it did not contain the Marine Vessel error (for Shelby Co) that had to be corrected in the previous modeling runs. It does not contain the error.

Relative to onroad mobile, we had previously sent you the following as I recall:

1. All Mobile6 input files for estimating VOC, NOx and CO for all county groups.
2. The TDOT report which had the linear growth rates in it
3. 1999 DVMT in excel file

We now have the 2001 DVMT files from TDOT--we received them last week. We need to add the local traffic to each county, so that it includes local VMT. We should have that done by next week and will forward it as soon as possible. There was a slight change in the way TDOT does VMT for 2000 and later. This results in about a 2.5% lesser total VMT for the state than their previous data showed. We will develop a new estimateof the linear growth rate in VMT and provide that to you within the next couple of weeks--that will be needed to estimate DVMT for 2007. That also means that the 2007 modeling that you did for the 1999 baseline and 2007 basecase has about a 2.5% higher VMT than it should--something that we may want to go back and correct at some point. Summarizing, we will send you the actual 2001 DVMT by county for use with the input files by next week and we will send you the appropriate VMT growth values to use, based on the starting point of using the 2001 DVMT within the next couple of weeks.

Let me know if you need any other information.

One final note: We were trying to use the Version 2 NEI data for Shelby Co which we received from Denis Fritchie--it seemed to have a number of errors and would not pass our QA that we were doing. We are not sure what is wrong with it--but be aware that it may have a problem. You may need to

contact Denis to see if it has a problem. I don't thing you ran into that earlier, as you were using the 1996 inventory and growing it.

Wayne

Version 1.0

Draft Technical Protocol

MODELING/ANALYSIS FOR THE ARKANSAS-TENNESSEE-MISSISSIPPI OZONE STUDY: 8-HOUR OZONE ATTAINMENT DEMOSTRATION

8 February 2001

SYSAPP-01/11

Prepared for

Arkansas-Tennessee-Mississippi Ozone Study Technical Committee
and
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Contents

1 INTRODUCTION AND STUDY DESIGN

This protocol document outlines the methods and procedures to be followed in conducting modeling and data analysis activities related to 8-hour ozone attainment for the Arkansas-Tennessee-Mississippi Ozone Study (ATMOS). The ATMOS modeling analysis is designed to provide technical information relevant to attainment of an 8-hour National Ambient Air Quality Standard (NAAQS) for ozone in the Memphis, Nashville, and Knoxville areas. This information is intended to provide the basis for attainment planning for each of the areas. In addition, the analysis will also provide information for addressing the emerging 8-hour ozone issues in the Hamilton County (Chattanooga), Tennessee; Lee County (Tupelo), Mississippi; and Little Rock, Arkansas areas. The modeling analysis will include an examination of the effects of the Regional NO_x SIP Call, Tier II motor vehicle and fuel standards, and possibly additional reductions in emissions of volatile organic compound (VOC) and oxides of nitrogen (NO_x).

Information regarding the organizational structure of ATMOS, study participants, communication structures, and the resolution of technical difficulties is presented in this section. The goals, objectives, and technical components of the modeling/analysis study are briefly described. Issues related to the study protocol are discussed and a schedule for the study is provided.

COMMITTEE COMPOSITION AND RESPONSIBILITIES

The Arkansas-Tennessee-Mississippi Ozone Study (ATMOS) is directed by three committees. A policy committee is composed of upper management persons from the state and municipal organizations funding the project. A technical committee is composed of persons with technical expertise from the participating entities. In addition, persons representing themselves or organizations not participating in the funding of this study may be members of the technical committee. An operations committee is composed of persons from the technical committee representing the principal states and organizations funding the project. In addition, a project manager is assigned. A Memorandum of Understanding (MOU) has been executed among the principal funding entities to effect a common agreement of the scope of work to be completed in ATMOS.

The policy committee secures funding for the project, enlists new members from entities wanting to participate in the funding, and makes final judgements on matters that cannot be resolved within the technical committee. At the time of this writing, the policy committee is made up of representatives from the states of Arkansas, Tennessee, and Mississippi as well as [to be completed following the 8-9 March 2001 meeting].

The technical committee directs the work of the contractor. This broad-based committee of stakeholders with technical expertise meets regularly to discuss and take action on specific tasks to be completed by the contractor. These tasks include, but are not limited to, procedures used to select episodes for modeling, development of appropriate emissions inventories, development of meteorological fields associated with the selected episodes, sensitivity runs of the photochemical grid model, control strategy runs for the photochemical

grid model, and presentation of results. These tasks and others are contained in a previously completed work plan and more specifically outlined within this protocol. The technical committee may in its judgement add to these tasks, subject to the needs of the members of the committee and availability of funding.

The operations committee is a subset of the technical committee and is composed of a member from each of the policy committee states and organizations drawn from the technical committee (including the Chairs) and the project manager (from SESARM) who will collectively approve the work products from the consultant for payment and make final decisions on the work products discussed among the full technical committee.

STUDY PARTICIPANTS AND THEIR ROLES

The principal participants in the study are those states and organizations that are funding the study. These include the states of Arkansas, Tennessee and Mississippi and the cities of Memphis, Nashville, Knoxville, and Chattanooga. In addition, a number of other organizations participate on the technical committee to advise and direct the study. At the time of this writing, these organizations include: U.S. Environmental Protection Agency (Regions IV and VI), Southeast States Air Resource Managers (SESARM), and ...[to be completed following the 8-9 March 2001 meeting].

The role of all the principal participants is somewhat greater than that of the other participants. The principal participants are funding the study and play a more direct role in the day-to-day operations and contact with the contractor. Final decisions on tasks and project management are made by the principal participants. The involvement of others is through their active participation on the technical committee.

The modeling and analysis tasks will be conducted by Systems Applications International, Incorporated (SAI). Jay Haney and Sharon Douglas will serve as co-project managers for SAI.

COMMUNICATIONS STRUCTURES

Communication among the participants occurs during bimonthly (approximately) face-to-face meetings of the technical committee, biweekly (approximately) teleconferences of the technical committee, and continuous (as necessary) e-mail and telephone. A web site set up by the consultant contains information and results generated in the study.

Communication between the contractor and the participants will be through the contractor's participation in the face-to-face and teleconference meetings, and by an e-mail distribution list. Outside of these meetings, communication between the contractor and the participants will be from the members of the operations committee (project manager and designated members).

SAI will report directly to SESARM and the ATMOS Technical Committee chairpersons.

RESOLUTION OF TECHNICAL DIFFICULTIES

Technical difficulties encountered by SAI will be brought to the attention of the Technical Committee chairpersons, either verbally or through written correspondence. SAI will also offer suggestions or recommendations on how to resolve such difficulties. All major issues or difficulties (whether or not they are fully or satisfactorily resolved during the course of the study) will be documented, in either a technical memorandum or the modeling/analysis report.

GOALS AND OBJECTIVES OF THE STUDY

The ATMOS modeling/analysis is designed to provide technical information related to 8-hour ozone issues in the Memphis, Nashville, Knoxville, Chattanooga, Tupelo, and Little Rock areas and surrounding portions of Arkansas, Tennessee, and Mississippi, and specifically to provide a basis for meeting regulatory modeling requirements and for longer-term decision making. These areas are likely to be included in designated nonattainment areas under a new 8-hour National Ambient Air Quality Standard (NAAQS) for ozone. This standard (in it's current draft form) requires the three-year average of the fourth highest ozone concentration for a given monitoring site to be less than 85 parts per billion (ppb). Initial compliance with this standard was scheduled to be determined using data collected during the period 1997-1999. Based on data for 1997-1999, the 1999 design values for the areas listed above are given in Table 1-1.

TABLE 1-1. 1997-1999 8-hour ozone "design values" for the ATMOS areas of interest.

Area (and state(s))	1997-1999 Design Value (ppb)
Memphis (AR, TN, MS)	95
Nashville (TN)	102
Knoxville (TN)	105
Chattanooga (TN)	95
Tupelo (MS)	87
Little Rock (AR)	83

Also of interest are the 1998-2000 design values for the areas of interest as given in Table 1-2. These will also likely be used in the application of the modeled attainment test, as described later in this protocol document.

TABLE 1-2. 1998-2000 8-hour ozone "design values" for the ATMOS areas of interest.

Area (and state(s))	1998-2000 Design Value (ppb)
Memphis (AR, TN, MS)	97
Nashville (TN)	102
Knoxville (TN)	102
Chattanooga (TN)	97
Tupelo (MS)	89
Little Rock (AR)	88

A designation of nonattainment relative to the 8-hour ozone standard may require that air quality modeling techniques be applied as part of an attainment demonstration. Thus, the primary objective of this study is to provide the modeling/analysis results needed to support an attainment demonstration for each of these areas. As such, the study has been designed in accordance with draft EPA guidance (EPA, 1999) for using modeling and other analyses for 8-hour ozone attainment demonstration purposes. Note the while the guidance is currently in draft form, the final version is not expected to be substantively different from the draft (EPA, personal communication).

The results of this study will be presented in a single report, with separate sections for the presentation of results for each area of interest. The analytical results will also be presented in electronic/database format such that each of the areas can be examined separately. In this manner, the study results will be easily referenced or directly incorporated into State Implementation Plan (SIP) documentation prepared by the state or local agencies. It is expected that the ATMOS modeling effort will be supplemented by additional state-, area-, or control-strategy specific model runs or analyses.

MODELING/ANALYSIS STUDY COMPONENTS

The ATMOS modeling analysis components include a comprehensive episode selection analysis (identifying suitable periods for modeling), application and evaluation of a photochemical modeling system for one simulation period, projection of emissions and ozone concentrations for one or more future years, and evaluation of ozone attainment strategies. While photochemical modeling is currently the best available and most widely used technique to estimate the effects of emission changes on future-year ozone air quality and to evaluate attainment strategies, EPA also recommends (EPA, 1999) that additional analysis of observational data be included as part of an attainment demonstration. Thus it is anticipated that future efforts may also include the analysis of observational data to corroborate the results and conclusions of the modeling analysis. All technical tasks will be conducted in accordance with draft EPA guidance regarding the use of modeling and other analyses for 8-hour ozone attainment demonstration (EPA, 1999). The documentation prepared as part of this study will be appropriate for inclusion as part of a SIP technical support document for each of the areas of interest.

PROTOCOL OBJECTIVES, CONTENTS, AND AMENDMENT PROCEDURES

This protocol document should be viewed as a set of general guidelines and is intended to provide focus, consistency, and a basis for consensus for all parties involved in the study.

The primary purpose of the protocol document is to outline the methodologies to be followed throughout the study. At this time some of the methodologies to be used in the modeling/analysis study have not been finalized. It will be necessary for the study participants to make decisions regarding these issues as the study progresses. Amendment of the protocol document will occur only upon the direction of the ATMOS Technical Committee chairpersons and following a review by the Technical Committee. Each time the protocol document is amended, a revised version of the entire document will be made available in electronic format on the ATMOS web site.

The remainder of this document provides detailed information on each element of the modeling/analysis. Selection of the primary modeling tools is summarized in Section 2 and

a brief overview of each is provided. The methods and results of the episode selection analysis are provided in Section 3. The modeling domain is presented in Section 4. Model input preparation procedures are described in Section 5. Model performance evaluation is discussed in Section 6. The use of diagnostic and sensitivity analysis is outlined in Section 7. Future-year modeling is discussed in Section 8. A description of the attainment demonstration procedures is given in Section 9. Documentation procedures are detailed in Section 10. The deliverables and schedule for the project are summarized in Section 11. Archival and data acquisition procedures are outlined in Section 12.

SCHEDULE

A schedule for the ATMOS modeling analysis is provided in Figure 1-1. The original ATMOS work (Phase I) was initiated in January 1999. The schedule presented in the earlier work plan for Phase II (dated October 2000) has been updated here to reflect a somewhat delayed start to the technical analysis – while the organization and funding details were being worked out.

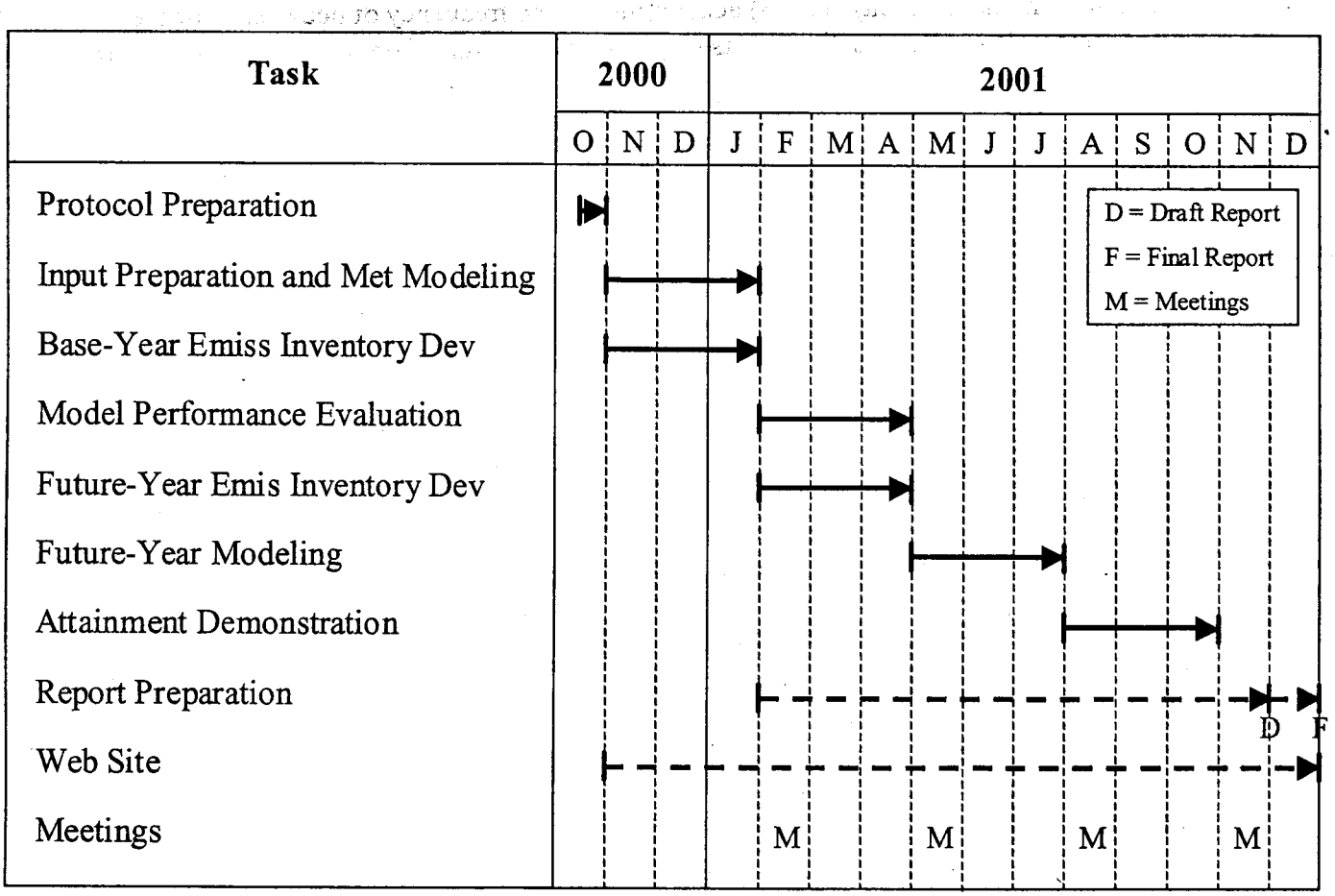


FIGURE 1-1. Schedule for Phase II of the ATMOS 8-hour ozone modeling study.

3 EPISODE SELECTION

Episode selection for the ATMOS modeling/analysis was based on a review of historical meteorological and air quality data, and application of an objective procedure for optimizing representation of typical ozone exceedance events across the areas of interest. The episode selection analysis was focussed on Memphis, Nashville, and Knoxville. The applicability of the episodes selected for these areas for modeling of Chattanooga, Tupelo, and Little Rock was also examined.

The primary objective of the episode selection analysis was to identify suitable periods for analysis and modeling related to the 8-hour ozone NAAQS for the Memphis, Nashville, and Knoxville areas. Important considerations include (1) representing the range of meteorological conditions that accompany ozone exceedances, (2) representing the ozone concentration levels that characterize the nonattainment problem (and result in the designation of nonattainment), and (3) accounting for the frequency of occurrence of the relevant meteorological/air quality events (to avoid using results from infrequent or extreme events to guide the decision making process).

The approach to episode selection is consistent with current (draft) EPA guidance (EPA, 1999) on episode selection for 8-hour ozone attainment demonstration modeling. In this guidance, EPA lists the following as the most important criteria for choosing episodes:

- Monitored ozone concentrations comparable to the severity as implied by the form of the NAAQS
- Representation of a variety of meteorological conditions observed to correspond to monitored ozone concentrations of the severity implied by the form of the NAAQS
- Data availability
- Selection of a sufficient number of days so that the modeled attainment test is based on several days

EPA also provides several additional (secondary) criteria for episode selection:

- Episodes used in previous modeling exercises
- Episodes drawn from the period on which the current design value is based
- Observed concentrations are "close" to the design value for as many sites as possible
- Episodes are appropriate for as many of the nonattainment areas as possible (when several areas are being modeled simultaneously)
- Episodes that include weekend days

METHODOLOGY

The methodology used for the episode selection analysis was based on that developed for a similar study by Deuel and Douglas (1998) and used for the several other modeling studies including GCOS (Douglas et al. 1999). A detailed description of the methods and results is presented by Douglas et al. (2000). For Memphis, Nashville, and Knoxville, days within the period 1990 to 1999 were classified according to meteorological and air quality parameters using the Classification and Regression Tree (CART) analysis technique.

The frequency of occurrence of ozone exceedances for each classification type was then determined for each area of interest. Days with maximum ozone concentrations within approximately 10 ppb of the respective design value were also identified. Design values were calculated for each area on a site-specific basis. For each area, the "regional" design value was then specified to be the maximum value among all sites in the area. For 8-hour ozone, the design value is the average of the fourth highest daily maximum concentration for each of the three years of the calculation period.

Next, an optimization procedure was applied to the selection of multi-day episodes for maximum achievement of the specified episode selection criteria (as outlined above). A combined optimization was performed for the three primary areas of interest.

Finally, a more detailed analysis of the episode days with respect to the location and number of exceedance sites as well as local meteorological conditions was conducted. The suitability of the episodes for modeling of Chattanooga, Tupelo, and Little Rock was also examined. Among these three areas, meteorological representativeness was only examined for Chattagnooga (using some CART results from a previous study).

RESULTS

In accordance with EPA guidance, the primary objectives of the episode selection analysis were to identify days that (1) represent the types of meteorological conditions that are most frequently associated with ozone exceedances and (2) have ozone concentrations that are representative of the design value. The guidance quantifies the latter with a range of 10 ppb.

In addition, several other considerations were used to guide the selection of multiple episode periods for modeling.

- It is important that the candidate modeling episode days encompass the range of meteorological conditions that accompany ozone exceedances (i.e., that all key meteorological regimes, or as many as feasible, are included).

- EPA guidance suggests that a modeling attainment test should include several days. For this analysis, this is assumed to be the number of days with maximum 8-hour ozone within 10 ppb of the design value for each area.

- Since the response of the modeling system to emission reductions can vary according to concentration level, some consideration was given to ensuring that the values within 10 ppb of the design were distributed about the design value and that several exceedance days were included for each area.

- Finally, cost and schedule were considered in selecting the final episode days (including the total number of simulation periods and days)

The episode selection algorithm was applied to the identification of candidate 8-hour ozone modeling episodes for the three areas of interest. As noted earlier, the objective was to identify episodes that are characterized by typical (frequently occurring) meteorological conditions, and maximum ozone concentrations that are close to the regional design values for the 1997-1999 period. In preparing this protocol document, we have also considered the design value for the 1998-2000 period. Each area was considered separately and as part of an integrated analysis. The integrated analysis was designed such that the selected episode days are representative of not just one, but two or more of the regions included in the analysis.

Following application of the objective episode selection procedures, a final set of episode days was selected such that (1) the best candidate modeling episodes (i.e., those best meeting the representativeness criteria given above) were included, (2) the significant meteorological regimes were represented, and (3) only episodes that occurred during 1997-1999 were included in the final list of candidate episodes. This was done for each ozone metric separately and for the integrated analysis.

In comparing the individual-area results, with the integrated results we found that some days that are good modeling candidates for one area are not good for another area and the best episodes for modeling all three areas may not represent the first choice for each area individually. Considering the criteria given above, the best overall candidate episode is 29 August – 9 September 1999. This rather long simulation period includes multiple days of interest for all three areas. The meteorological and air quality characteristics of the this set of days are summarized in Table 3-1 for Memphis, Nashville, and Knoxville.

TABLE 3-1a. Summary of maximum 8-hour ozone concentration and meteorological regime for the 29 August – 9 September 1999 episode days for Memphis. Exceedances and key meteorological regimes (CART bins) are highlighted in bold.

Year	Month	Day	Maximum 8-Hour Ozone (ppb)	CART Bin[1]
1999	8	29	79	22
1999	8	30	71	20
1999	8	31	**96**	15
1999	9	1	**87**	**21**
1999	9	2	**95**	**34**
1999	9	3	**97**	**18**
1999	9	4	**106**	29
1999	9	5	64	35
1999	9	6	80	2
1999	9	7	**87**	26
1999	9	8	55	25
1999	9	9	49	4

[1] Key exceedance bins for Memphis are 21, 18, and 34. Other potentially important bins are 15 and 26.

TABLE 3-1b. Summary of maximum 8-hour ozone concentration and meteorological regime for the 29 August – 9 September 1999 episode days for Nashville. Exceedances and key meteorological regimes (CART bins) are highlighted in bold.

Year	Month	Day	Maximum 8-Hour Ozone (ppb)	CART Bin[2]
1999	8	29	74	30
1999	8	30	65	10
1999	8	31	**92**	4
1999	9	1	**100**	**11**
1999	9	2	**91**	12
1999	9	3	**91**	25
1999	9	4	**110**	**26**
1999	9	5	**109**	**26**
1999	9	6	**96**	**11**
1999	9	7	79	13
1999	9	8	**89**	25
1999	9	9	60	30

TABLE 3-1c. Summary of maximum 8-hour ozone and meteorological regime for the 29 August - 9 September 1999 episode days for Knoxville. Exceedances and key meteorological regimes (CART bins) are highlighted in bold.

Year	Month	Day	Maximum 8-Hour Ozone (ppb)	CART Bin[3]
1999	8	29	84	36
1999	8	30	82	20
1999	8	31	**90**	22
1999	9	1	**105**	**32**
1999	9	2	**104**	**32**
1999	9	3	**101**	33
1999	9	4	**107**	**32**
1999	9	5	**90**	35
1999	9	6	**86**	**32**
1999	9	7	**102**	**21**
1999	9	8	**98**	**32**
1999	9	9	**86**	28

The representativeness of these days for each of the three primary areas of interest is summarized in Table 3-2 – first with respect to the 1997-1999 design values (Table 3-2a) and then with respect to the 1998-2000 design values (Table 3-2b). Days with maximum

[2] Key exceedance bins for Nashville are 11, 26, 16, and 28. Other potentially important bins are 23, 19, and 22.

[3] Key exceedance bins for Knoxville are 32, 21, and 15. Other potentially important bins include 37, 27, 36, 19, and 33.

concentrations within 10 ppb of the design value are marked with a single asterisk. Of these days, those within a key meteorological regime are given a second asterisk.

TABLE 3-2a. Summary of representativeness of recommended simulation periods 8-hour ozone for Memphis, Nashville, and Knoxville. Concentrations within approximately 10 ppb of the regional design values was based on the 1997-1999 design values of 95, 102 and 105 ppb for Memphis, Nashville, and Knoxville, respectively.

Year	Month	Day	Memphis	Nashville	Knoxville
1999	8	29			
1999	8	30			
1999	8	31	*	*	
1999	9	1	**	**	**
1999	9	2	**	*	**
1999	9	3	**	*	*
1999	9	4	*	**	**
1999	9	5		**	
1999	9	6		**	
1999	9	7	*		**
1999	9	8			**
1999	9	9			

TABLE 3-2b. Summary of representativeness of recommended simulation periods 8-hour ozone for Memphis, Nashville, and Knoxville. Concentrations within 10 ppb of the regional design values was based on the 1998-2000 design values of 97, 102, and 102 ppb for Memphis, Nashville, and Knoxville, respectively.

Year	Month	Day	Memphis	Nashville	Knoxville
1999	8	29			
1999	8	30			
1999	8	31	*	*	
1999	9	1	**	**	**
1999	9	2	**	*	**
1999	9	3	**	*	*
1999	9	4	*	**	**
1999	9	5		**	
1999	9	6		**	
1999	9	7	*		**
1999	9	8			**
1999	9	9			

The 29 August - 9 September 1999 includes:

- six 8-hour exceedance days, six days within approximately 10 ppb of the 1997-1999 design value, six days within 10 ppb of the 1998-2000 design value, and three of three key meteorological regimes (plus two other regimes) for Memphis

- eight 8-hour exceedance days, seven days within approximately 10 ppb of the 1997-1999 design value, seven days within 10 ppb of the 1998-2000 design value, and two of four key regimes (plus three other regimes) for Nashville

- ten 8-hour exceedance days, six days within approximately 10 ppb of the 1997-1999 design value, six days within 10 ppb of the 1998-2000 design value, and two of three key regimes (plus four other regimes) for Knoxville

FURTHER ANALYSIS OF THE 29 AUGUST –9 SEPTEMBER 1999 SIMULATION PERIOD

The candidate modeling episode was further examined with respect to site-specific ozone concentrations and potential source-receptor relationships. Ozone and meteorological conditions for Chattanooga as well as ozone concentrations for Tupelo and Little Rock were also examined.

Distribution of Exceedances for the Memphis Area

The 29 August - 9 September 1999 episode contains several exceedance days for each of the four sites. Exceedances of the 8-hour standard occurred at the Crittenden County, AR monitoring site on 31 August, 3 September, and 7 September (the values are 92, 97, and 87 ppb, respectively). Exceedances occurred at the DeSoto County, MS monitoring site on 31 August and 3 September, with a near exceedance on 7 September (the values are 92, 93, and 83 ppb, respectively). Exceedances occurred at one or both of the Shelby County sites on 31 August, and 1, 2, 3, and 4 September (with a near exceedance on 7 September). While exceedances occur at the Crittenden and Desoto County sites on the same days, it is interesting that concentration differences for these sites are as large at 20 ppb on other days, indicating different local wind directions. A couple of days have high values in Shelby County but low values at the AR and MS monitors. Thus it appears that this episode captures a variety of different concentration patterns (source-receptor relationships) and accommodates all three sub-areas in terms of including exceedance days (10 ppb days) for each. Exceedances were recorded at all four monitoring sites.

Distribution of Exceedances for the Nashville Area

All sites have two or more exceedances (most have five or more) during the period 29 August - 9 September 1999 and the location of the maximum value varies by day. So again this appears to be an interesting episode and a good candidate to capture variable concentration patterns and different source receptor relationships.

Distribution of Exceedances for the Knoxille Area

All sites experienced two or more exceedances during the period 29 August - 9 September 1999. Concentrations are generally higher and there are more exceedance days at the higher elevation (National Park Service) sites in Sevier and Blount Counties. Within Knox County one site has three exceedance days, while the other has five. Concentrations reached 101 ppb at the more urban sites. Look Rock by comparison has eight exceedance days with a maximum value on 4 September of 107 ppb. This episode appears to capture both

exceedances in the urban area as well as the tendency for the higher and more persistent values at the higher elevation sites.

Representativness of the Simulation Period for Chattanooga

We were fortunate to have CART results from a previous study (Douglas and Hudischeswkyj, 1999) to aid in the assessment of whether the episode days were suitable for Chattanoonga. The CART analysis was supplemented with data for 1999 and the episode days were reviewed with respect to meteorological regime and ozone concentration. The 29 August – 9 September 1999 period includes six exceedance days for Chattanooga. These repesent three of the four key exceedance regimes and one additional regime. Five of the days are within 10 ppb of the 1997-1999 design value of 95 ppb. Six of the days are within 10 ppb of the 1998-2000 design value of 97 ppb. This is a very good modeling episode for Chattanooga.

Ozone Concentrations for Tupelo (Lee County, MS)

In contrast, the 29August – 9 September 1999 episode is rather severe for this area with four exceedance days and 8-hour values of 98 ppb on 2 September, 86 ppb on 3 September, 94 ppb on 6 September, and 96 ppb on 7 September. The 1997-1999 design value is 87 ppb (the fourth highest maximum value for 1999 occurred on 6 September).

Ozone Concentrations for Little Rock (Pulaski County, AR)

During 29 August – 9 September, there is one exceedance and one near exceedance of the 8-hour standard. Unfortunately, the exceedance occurred on 29 August, one of the start up days for the episode. The second highest value (83 ppb) occurred on 3 September. This value is consistent with the 1997-1999 design value of 83 ppb and is thus an acceptable modeling episode day for Little Rock. The design value for 1998-2000 is 88 ppb.

SUMMARY AND RECOMMENDATIONS

In summary, it appears that the 29 August - 9 September 1999 period provides a good basis for modeling for all three areas from the perspective of capturing a variety of concentration patterns and levels for most monitoring sites. For Memphis, sites in all three states are accommodated.

An alternate or possible second episode 1-9 August 1999 contains fewer exceedance days (and represents fewer of the key meteorological regimes), but also includes good modeling days for most sites and areas. For Memphis, however, this episode seems to primarily affect DeSoto County.

CONCEPTUAL DESCRIPTION

The results of the episode selection analysis (including the CART results) provide descriptive information about the type of meteorological (and regional air quality) conditions that lead to high ozone in the areas of interest. This information will be used to guide the modeling analysis and the development of any conceptual descriptions of the ozone air quality and nonattainment issues that emerge from the modeling results.

6 MODEL PERFORMANCE EVALUATION

A typical application of the UAM-V modeling system for ozone air quality assessment purposes consists of several simulations, including an initial simulation and a series of diagnostic and sensitivity simulations (designed to examine the effects of uncertainties in the inputs on the simulation results, identify deficiencies in the inputs, and investigate the sensitivity of the modeling system to changes in the inputs). For each simulation, model performance is primarily assessed through graphical and statistical comparison of the simulated pollutant concentrations with observed data. The results of this comparison are used to guide the modeling analysis (through the determination of additional diagnostic and sensitivity simulations) and to assess whether the model is able to adequately replicate the air quality characteristics of the simulation period. Model performance evaluation tests and procedures are described in this section. Diagnostic and sensitivity analyses that may be performed to understand and improve model performance are discussed in Section 7.

EPA guidance (EPA, 1999) stresses the need to evaluate the model relative to how it will be used in the attainment demonstration; that is in simulating the response to changes in emissions. Various aspects of the model performance evaluation, such as assessment of the ability of the model to simulate weekday-weekend differences in concentration levels and patterns, detailed evaluation of the changes in process-level contributions, and comparison with air quality and emissions trends will be used to evaluate the reliability of the modeled response.

Once acceptable model performance is achieved (based on the results of the graphical, statistical, and sensitivity analysis), the simulation is subsequently referred to as the base-case simulation. The establishment of a base-case simulation is integral to the reliable use of the modeling system to assess the effects of changes in emissions on future air quality.

This section of the protocol document describes the procedures to be used to evaluate model performance.

MODEL PERFORMANCE DATA

Data from all air quality monitoring sites within the ATMOS modeling domain will be used in the evaluation of model performance. For the most part, these include measurements of ozone, NO, NO_2, NO_x, and CO for routine monitoring sites (including photochemical assessment monitoring sites, PAMS) located throughout the region (and primarily in the urban/nonattainment areas). These data will be obtained from AIRS. We will supplement this database with data from the CASTNET and SCION monitoring program. Several CASTNET and SCION monitors are located throughout the Southeast. Data from these sites will typically include higher resolution NO_x measurements (compared to the routine monitoring sites) and may also include measurements of hydrocarbon species. Data from special studies commensurate with the simulation periods will also be solicited and incorporated as time and resources permit. Note that the analysis and use of special-study data can sometimes be very resource intensive.

MODEL PERFORMANCE OBJECTIVES

As noted earlier, the overall objective of a model performance evaluation is to establish that the modeling system can be used reliably to predict the effects of changes in emission reductions on future-year ozone air quality and to evaluate the effectiveness of possible attainment demonstration strategies. Specific objectives for the ATMOS study include: (1) ensuring that the regional-scale modeling results provide appropriate boundary conditions for the primary area of interest (Grid 3), (2) ensuring that the ozone concentration patterns and levels and the day-to-day variations in these are well represented, and (3) ensuring that the modeling system exhibits a reasonable response to changes in the inputs (and that the inputs do not contain significant biases or compensating errors).

MODEL PERFORMANCE EVALUATION PROCEDURES

The evaluation of model performance will follow the general procedures outlined in this section. Variations to these may be proposed and incorporated during the course of the study to address specific issues that arise. All additions/changes will be discussed with the ATMOS Technical Committee.

Model Performance Evaluation Components

The evaluation of model performance will include both qualitative and quantitative components. For each simulation conducted as part of the base-case modeling analysis, a variety of graphical and statistical analysis products will be prepared. These are listed and described in the remainder of this section and will provide the basis for the model performance evaluation. The analysis and integration of these results, relative to the objectives (as given earlier in this section), will complete the evaluation of model performance.

Geographical Considerations

The simulation results for the full domain and each subdomain will be examined using a variety of graphics, metrics, and statistics (these are summarized later in this section). Analysis of results for the coarse-grid (36 and 12-km resolution) domains will emphasize representation of the regional-scale concentration levels and patterns, as well as day-to-day variations in regional-scale air quality. Statistics will be calculated for the coarser grids, but are not expected to be very meaningful for the scale represented by these grids (due to the fact that the data are representative of a much smaller scale). A more detailed analysis of the results will be performed for the high-resolution (4-km) grid and subregions thereof. This will include the analysis of the magnitude and timing of site-specific concentrations (1-hour and 8-hour), a more rigorous statistical evaluation (compared to the coarser grids), and the use of process analysis (for selected simulations for all or portions of Grid 3).

Temporal Considerations

The ability of the modeling system to depict the day-to-day differences in ozone concentration, as indicted by the observations, will be examined for each domain and episode period. Diurnal variations in ozone for the coarser grids will be examined relative to the boundary condition estimates for the finer grids. Site-specific, hourly variations for

ozone and precursor species will be examined (using time-series plots and statistical measures) for sites within the high-resolution domains.

The analysis of model performance will focus on 1-hour concentrations of ozone and other species, since the data are typically reported as hourly values. However, the ability of the model to represent maximum 8-hour ozone concentration is related to its ability to represent the hourly values that comprise the 8-hour maximum. Thus, a comparison of maximum 8-hour average ozone concentration will also be performed for the high resolution grids.

As the modeling study progresses, variations in model performance among the simulation periods will also be examined. Specifically, differences in model performance among the simulation periods will be documented and reasons for the differences will be examined.

Species

All relevant species represented by the observed data within the high-resolution domains will be included in the model performance evaluation. We will also consider the calculation of ratios or other derived parameters. The use and interpretation of ratios will be based on discussions with the ATMOS Technical Committee.

Summary of Graphical Displays, Metrics, and Statistical Parameters

Graphical displays and statistical/tabular summaries of the UAM-V simulation results will provide the basis for model performance evaluation and will be used to guide the interpretation and use of the UAM-V simulation results. For each simulation performed as part of the base-case modeling analysis, the graphical displays and tabular summaries will include:

- Isopleth plots of daily maximum simulated ozone concentration (1-hour and 8-hour), with observed values overplotted for all UAM-V grids
- Time-series plots (with range shading) of hourly ozone, NO, NO_2, NO_x, VOC, and CO concentrations for each monitoring site (and possibly other unmonitored locations) within Grid 3
- Scatter plots of hourly ozone (and possibly NO, NO_2, NO_x, VOC, and CO concentrations and selected indicator species) for monitoring sites within Grids 1, 2, and 3
- Scatter plots of 8-hour maximum ozone concentration for each monitoring site within Grids 1, 2, and 3
- Scatter plots comparing the time of the simulated and observed 8-hour maximum ozone concentrations for each monitoring site within Grids 1, 2, and 3
- Standard SAI list of 20 metrics and performance statistics for 1-hour ozone (as listed in Table 6-1, these include various max, min, mean, accuracy, bias, error, residual, and ratio-based parameters) for Grids 1, 2, and 3
- EPA recommended average accuracy statistics for 8-hour ozone

- Time-series plots and bar charts of selected metrics and statistics for ozone for Grids 1, 2, and 3

- Animations of simulated ozone concentrations for selected grids/levels (and selected simulations)

These plots and tabular summaries will be used to display/convey the results of a single simulation or to compare two different simulations, as appropriate. In the latter case, the plots and animations may be presented as concentration differences.

If the UAM-V process-analysis technique is employed for a given simulation, the process-analysis results (for ozone, NO_x, and VOC) will be displayed using SAI's standard 3-panel plots which show the hourly contribution (separately and cumulatively) and the daily net contribution for each simulation process. These will be used to display the results of a single simulation or to compare two different simulations, as appropriate.

DETERMINATION OF ACCEPTABLE MODEL PERFORMANCE

An integrated assessment of the above information (obtained as part of the base-case modeling analysis) will be used to document and qualitatively and quantitatively assess whether an acceptable base-case simulation has been achieved. Certain of the statistical measures will be compared to the EPA recommended ranges for acceptable model performance for urban-scale photochemical model applications. EPA has provided ranges for three key statistical measures for 1-hour ozone. The measures and recommended ranges are as follows: unpaired accuracy of the peak concentration (± 20 percent), normalized bias (± 15 percent), and normalized gross error (35 percent). We will also examine the average accuracy of the peak concentration and compare this with the range for the unpaired accuracy. These criteria are most applicable for the assessment of model performance for the high-resolution grid and/or selected urban-scale subregions thereof. However, they will also be used to guide the assessment of model performance for the regional-scale domains (Grids 1 and 2). The additional statistical measures recommended by EPA in the draft guidance for 8-hour ozone modeling will also be calculated and compared with the recommended ranges. These include the domain-wide average accuracy of the 8-hour ozone peak and the site-specific average accuracy of the peak over all simulation days. The recommended range for both of these measures is ± 20 percent. The 8-hour statistics will be calculated for the high-resolution grid and selected subregions only.

USE OF MODEL PERFORMANCE RESULTS TO GUIDE THE INTERPRETATION AND USE OF MODELING RESULTS IN THE ATTAINMENT DEMONSTRATION

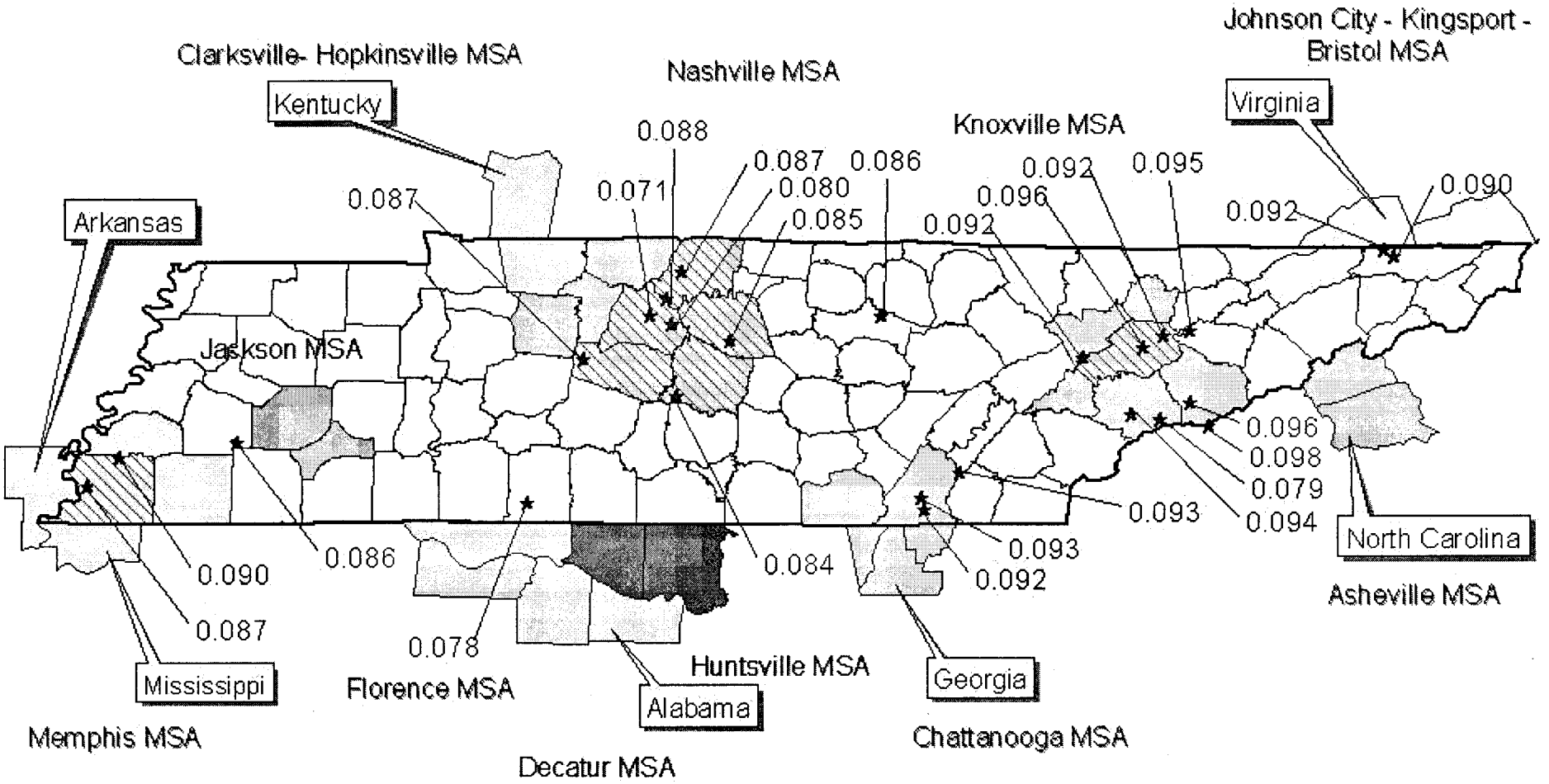
Information obtained as part of the model performance evaluation will be carried through the analysis and used to guide the interpretation and use of the results in the attainment demonstration. A simple example of such use is the case where ozone concentrations are overestimated for one or more sites in the base-case simulation. It is possible that the overestimation could affect the response of the modeling system to emissions changes. If the site(s) for which ozone is overestimated show a different result in the attainment demonstration than most other sites, and there are no other apparent reasons for these differences, the overestimation might explain the different response. This would be further

examined and possibly offered as "weight of evidence". As a second example, differences in model performance among days or episodes might cause a different weighting of the results in the attainment demonstration analysis.

TABLE 6-1. Standard list of UAM-V simulation metrics and performance statistics.

Number of data pairs
Maximum domain-wide simulated value
Max station-wide sim value
Maximum observed value
Domain-wide unpaired accuracy
Station-wide unpaired accuracy
Average accuracy of peak
Normalized bias
Normalized gross error
Fractional bias
Fractional gross error
Ratio of bias to mean observation
Ratio gross error to mean observation
Maximum residual
Minimum residual
Mean unsigned error
Mean residual
Mean simulated value
Mean observation
Root mean square error
Standard deviation of fractional bias

Tennessee 8 Hour Ozone
Design Values By MSA 2000 - 2002



Notes:
Design values in parts per million.
Old 1-hr nonattainment areas in hatched areas.
A county with a design value greater than or equal to 0.085 ppm is violating the standard.

★ **Monitoring Sites With an 8 Hr Ozone DV**